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A new mesh evolution algorithm to enable improved rework shape optimisation of complex 3-D structures

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Abstract

The Defence Science and Technology Organisation (DSTO) has developed a unique rework shape optimisation approach that has been successfully applied for repair of cracked aircraft structures. The optimal rework not only removes the crack but also reduces the local stress concentration and therefore deters re-cracking after the repair.

The design of optimal rework shape usually involves iterative 3-D finite element analysis. A proper mesh evolution approach is therefore needed to automate the optimal design process. In previous applications, the local geometries to be reshaped can often be idealised into a plate-like structure, and therefore can be discretised using structured meshes with cubic elements. In these applications, mesh evolution can be achieved by pre-defined spatial interpolations between master point pairs at fixed and reshaped boundaries. Nevertheless, the simple spatial integration approach does not apply in recent applications that involve complex 3-D structures, where irregular meshes with tetrahedral elements have to be used. Hence, a new mesh evolution algorithm – based on a real-time closest points search and evolving movement weight functions – was developed and integrated with the existing DSTO rework optimisation code.

The purpose of this paper is to introduce the details of this new mesh evolution algorithm and the new capabilities it has enabled for optimal rework design in real applications. The major new capabilities include: (i) optimising parts with an irregular mesh of tetrahedral elements, such that existing aircraft loads model can be used with local refinement, to avoid inaccuracy of boundary conditions in an otherwise sectioned model; (ii) robust rework design considering perturbation of shape orientations of a non-circular optimal hole within structures where load perturbation cannot be applied; (iii) 2.5-D optimisation of non-planar structures; and (iv) streamlined development of family of optimal shapes by finite element analysis.